Pre-flight Testing and Performance of a Ka-band Software Defined Radio

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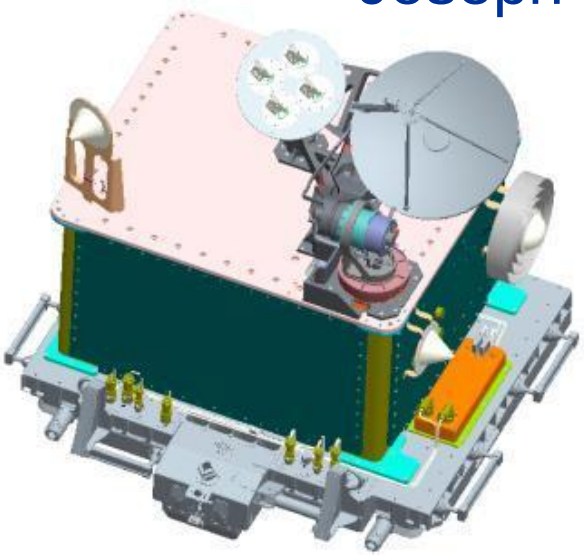


Outline

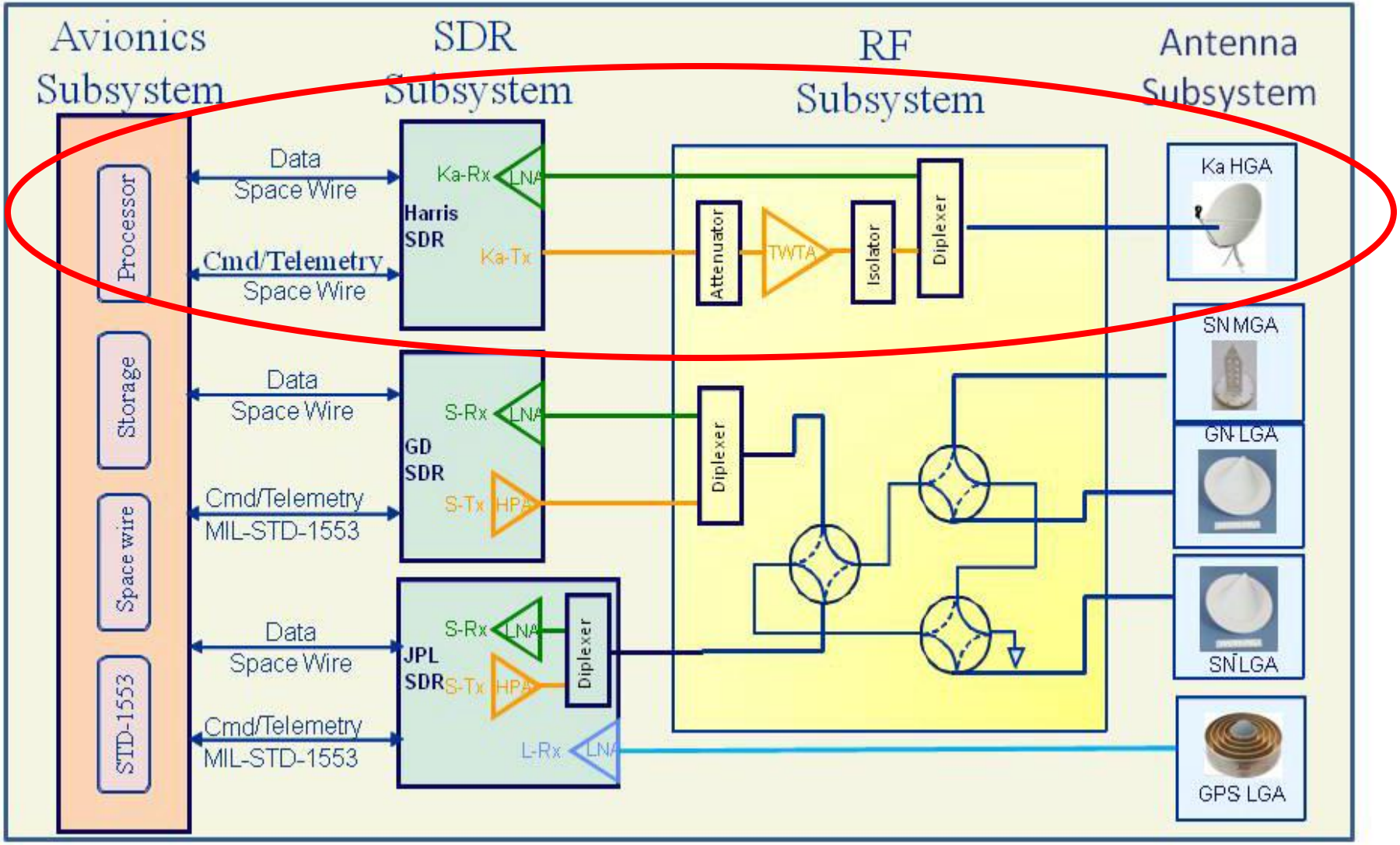
- Background
- Ka-band SDR
- Testing
- Performance Results
- Future Work

Background

- NASA is studying the development, testing, and operation of software defined radios (SDRs) for the space environment
- NASA has built a reconfigurable testbed comprised of SDRs for the space environment

- SCaN Testbed
  - 3 SDRs
  - Space Telecommunications Radio System (STRS)-compliant
  - L-band, S-band, Ka-band

SCaN Testbed Flight System Connections



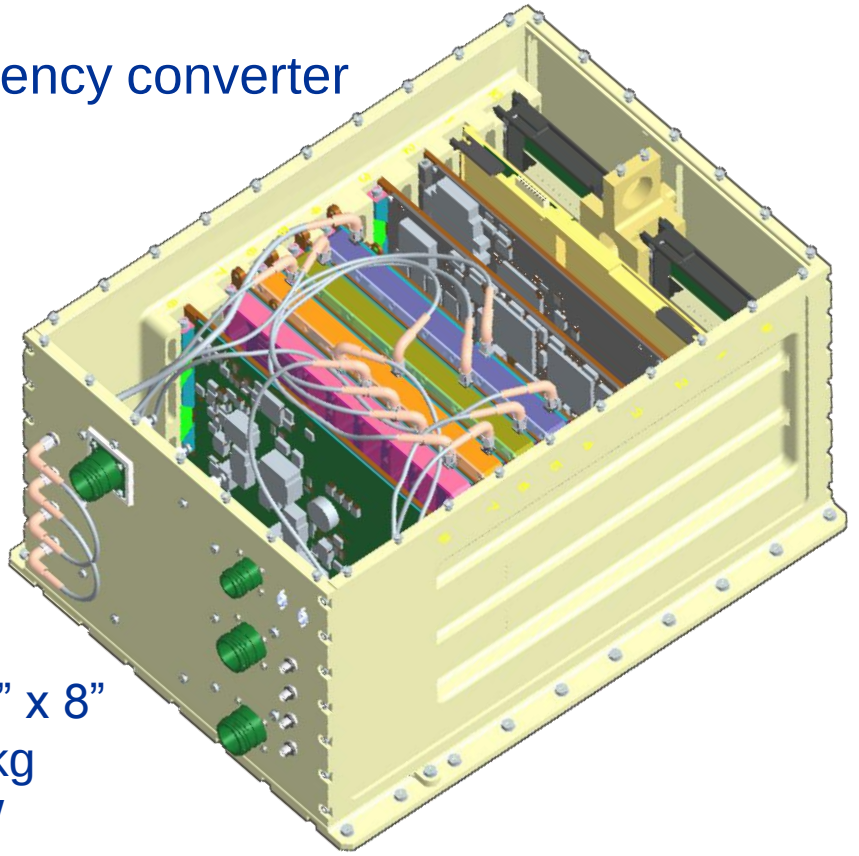
Harris Corporation Ka-band SDR

- Reconfigurable / Reprogrammable Signal Processing
  - Field Programmable Gate Arrays (FPGAs)
  - Digital Signal Processor (DSP)
  - Single Board Computer, PowerPC
- STRS-compliant Operating Environment
  - Manages waveform applications
  - Command / Telemetry
- Tunable RF front-end, designed for the TDRSS* Ka-band Service
  - Receive: 22.515 – 23.115 GHz
    - 50 MHz bandwidth
  - Transmit: 25.65 – 26.16 GHz
    - 225 MHz bandwidth

*TDRSS: Tracking and Data Relay Satellite System

Harris SDR Hardware

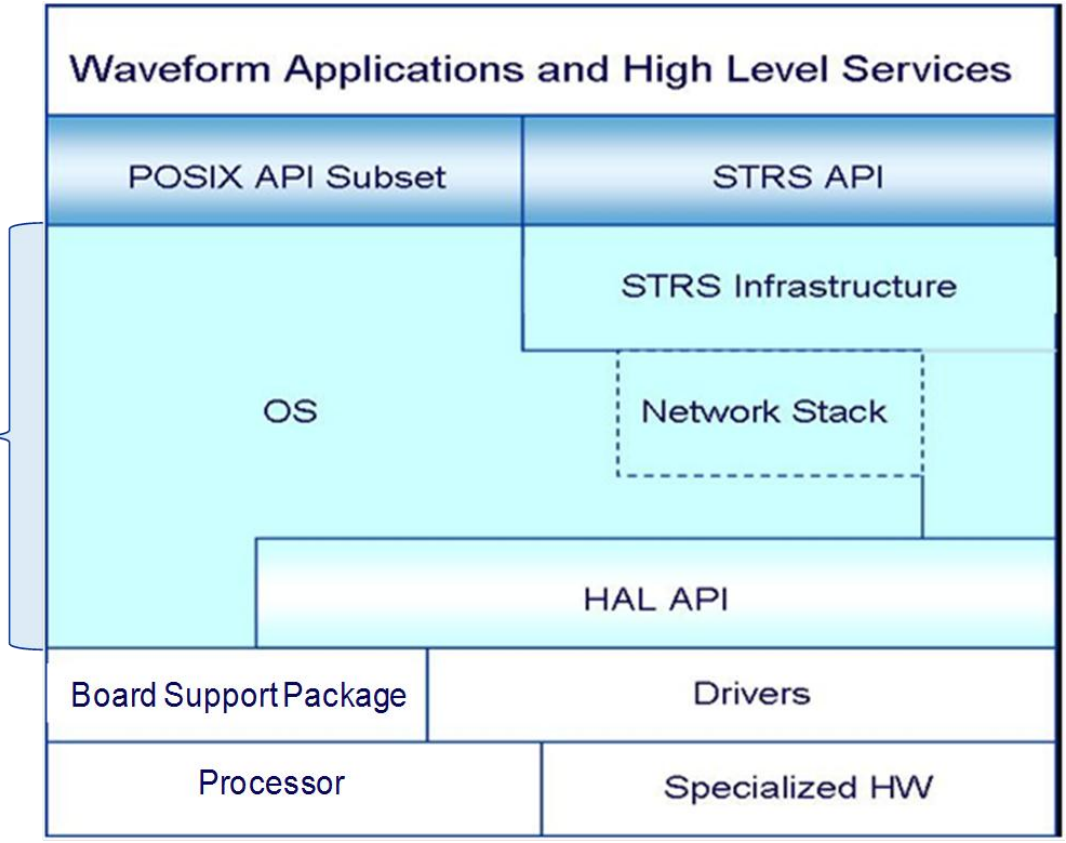
- Features
  - Modular architecture
  - Mixture of commercial and custom cards
  - 6U Compact-PCI backplane
  - External S-band to Ka-band frequency converter
- Modem Processor
  - Virtex IV FPGAs, DSP
  - Management ASIC
    - Scrubbing
    - Configuration
  - Internal SpaceWire Router



Size: 16” x 10” x 8”
Weight: 19.2 kg
Power: 100 W

Harris SDR Software

- Waveform Application
  - GPP
  - Specialized Processing
- Third Party Application Development
  - Development environment for third party waveform developers



Waveform Application

- Baseline Waveform developed by Harris Corporation
- Resource consumption
  - ~1/2 of FPGA resources (includes triple-mode-redundancy)
  - Does not use DSP

	Transmit	Receive
Frequency	25.65 GHz	22.6795036 GHz
Data Rate	300 kbps to 100 Mbps	300 kbps to 25 Mbps
Modulation	Offset-QPSK	BPSK
Line-code	NRZ-L,-M	
Coding	Convolutional, Rate ½, k=7	
Framing	CCSDS 732.0-B-2	
Randomization	CCSDS 131.0-B-2	

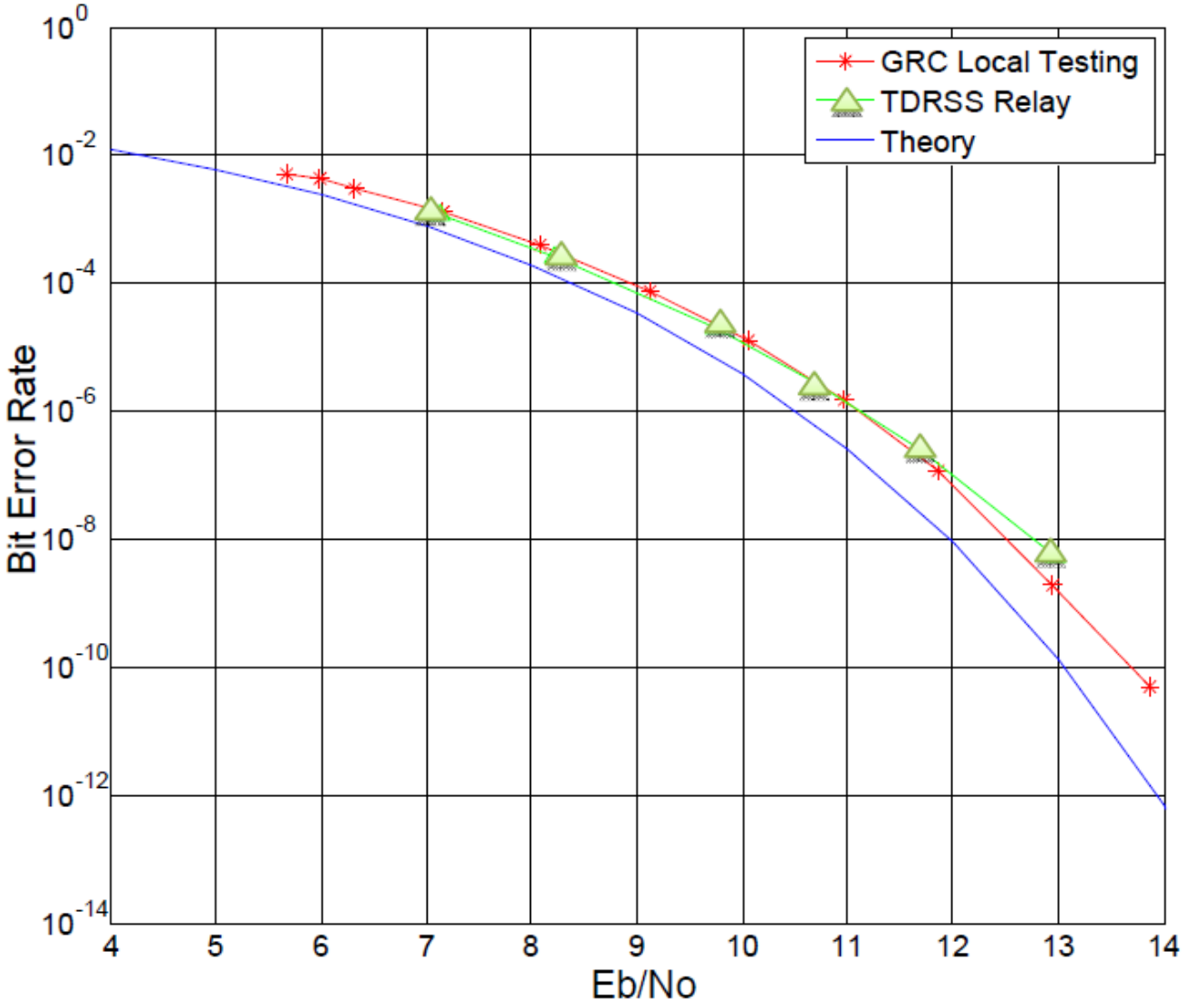
Testing

- Extensive testing performed at subsystem and integrated system level
  - TDRSS Compatibility
  - Environmental: Vibration, Thermal, Thermal Vacuum, EMI / EMC
- Pre-flight system performance will be basis for on-orbit evaluation
  - Minimum Signal Level Tracking / Acquisition Threshold
  - Acquisition Time, False Lock susceptibility
  - Coded and Uncoded BER performance vs Eb/N0
  - Frequency Control, Frequency Tracking Range
  - Transmitter Output Spectrum/Spectral Mask
  - Carrier Suppression
- Separation of Platform and Waveform Performance.
  - Platform limited by hardware
  - Waveform limited by implementation

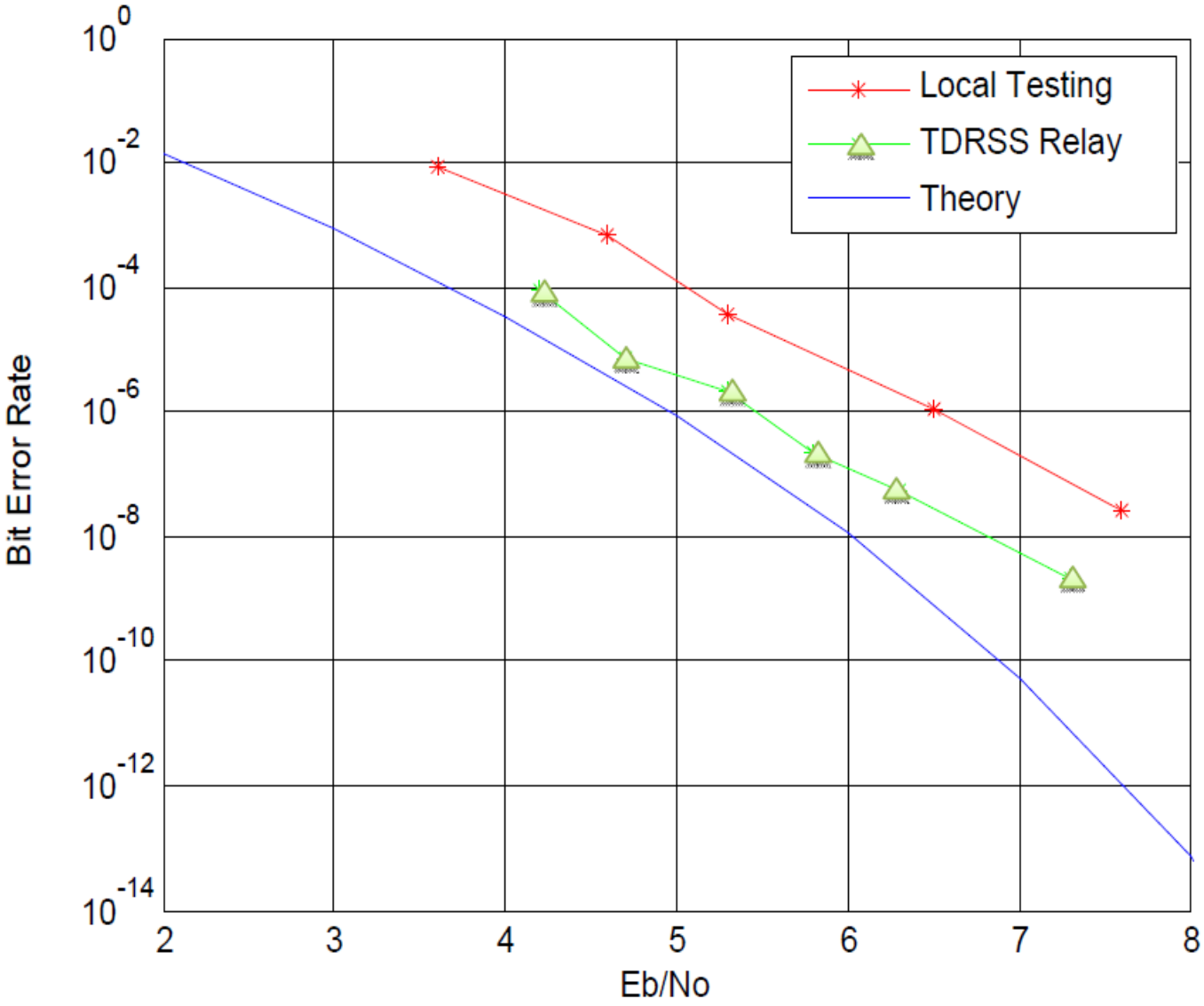
Performance Highlights

		Receive	Transmit
Platform	**Bandwidth**	129.6 MHz, -3 dB	239 MHz, -3 dB
	Frequency Setability	0.4 ppm	0.43 ppm
	Frequency Stability	0.02 ppm	
	Dynamic Range	-110 to -30 dBm	
	Noise Figure	2.3 dB (@ 25 C)	
	Spurious		No in-band 60 dBc No out-of-band 60 dBc
Waveform	**Acquisition Threshold**	-91.2 dBm (12.5 Mbps)	
	Tracking Threshold	-94.5 dBm (12.5 Mbps)	
	Doppler Tracking (+/- 15 kHz)	1.2 MHz/second	
	Acquisition Frequency	+/- 45 kHz	
	Implementation Loss	0.3 dB @ 12.5 Mbps	
	Carrier Suppression		>45 dB
	Phase Imbalance		±0.5°
	Gain Imbalance		±0.05°

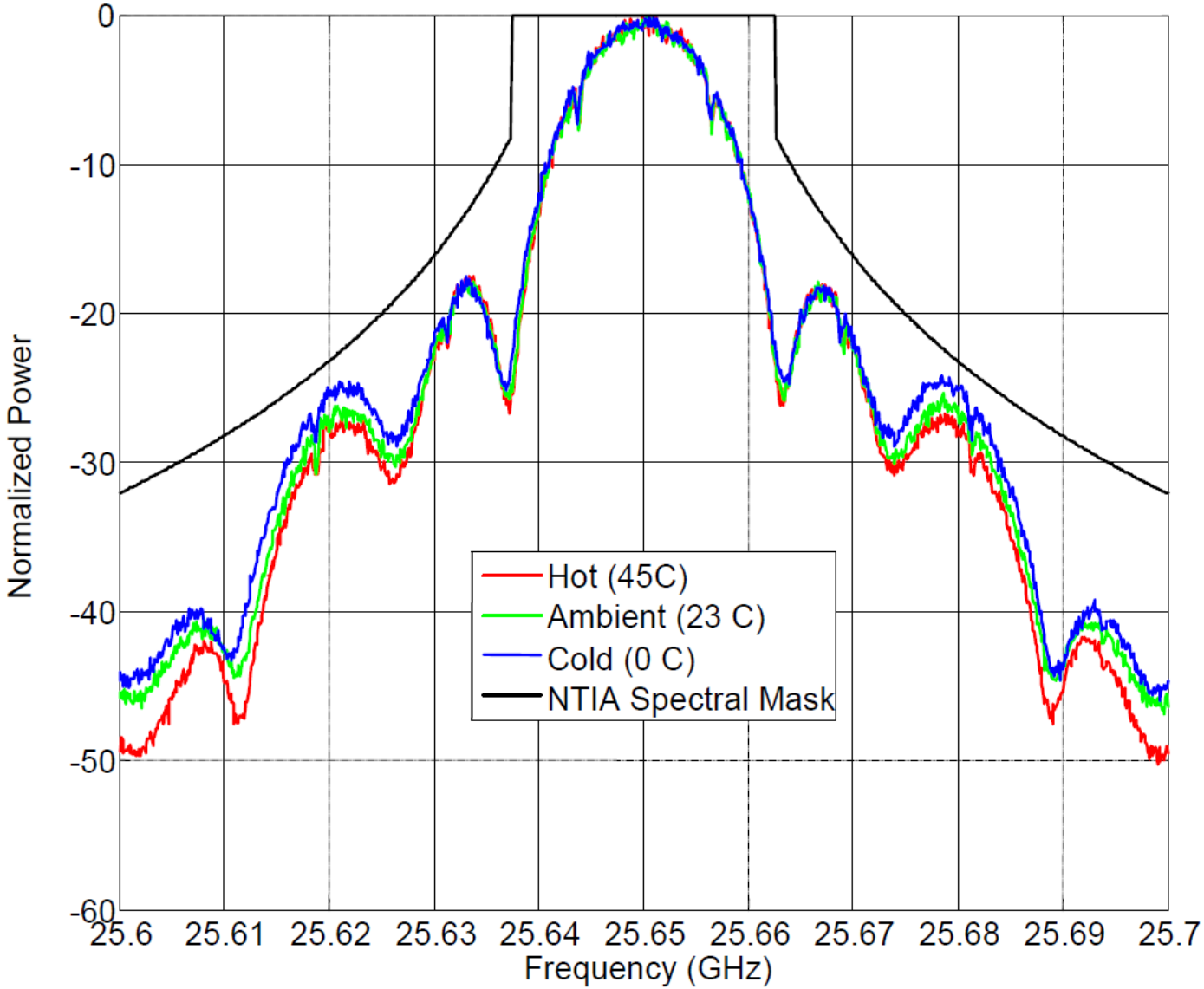
Receiver Uncoded Performance, 12.5 Mbps



Transmitter Coded Performance. 100 Mbps



Transmitter Spectrum, Spectral Mask



Future Experiment Use Planned

- Characterize Future NASA Communication System Infrastructure
  - Reconfigure SDR to emulate different missions
  - Reduces risk to science missions as new services/equipment are brought on-line
- Modern Forward Error Correction Codes
  - Low Density Parity Check,
  - Serial Concatenated Convolutional Codes
- Bandwidth Efficient Modulation
  - NASA technology programs looking to incorporate BW efficient modulations e.g. GMSK, 8-PSK
- Delay/Disruption Tolerant Networking (DTN)
- Adaptive Coding/Modulation

Summary

- Space Ka-band SDR transceiver on-orbit and ready for operation
- Excellent pre-flight testing performance, basis for space operations
- Ka-band SDR offers high flexibility, software/firmware defined
  - Other Ka-band space qualified modulators (e.g. GSFC High-Rate Modulator, General Dynamics HRT and Small Deep Space Transponder) employ reconfigurable (predefined) or fixed capability
- Experiment Proposals Welcome:
  - NSPIRES (Universities – Limited Funding)
    - http://nspires.nasaprs.com/external/index.do
  - Fedbiz Ops (Commercial/Non-profit - Unfunded)
    - https://www.fbo.gov/
  - Project Website (Info)
    - http://spaceflightsystems.grc.nasa.gov/SOPO/SCO/SCaNTestbed